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Clinical Article

Brain Injuries during Intraoperative Ventriculostomy in the Aneurysmal Subarachnoid Hemorrhage Patients

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Objective : Intraoperative ventriculostomy is widely adopted to make the slack brain. However, there are few reports about hemorrhagic or parenchymal injuries after ventriculostomy. We tried to analyze and investigate the incidence of these complications in a consecutive series of patients with aneurysmal subarachnoid hemorrhage (SAH).

Methods : From September 2006 to June 2007, 43 patients underwent surgical clipping for aneurysmal SAH at our hospital. Among 43 patients, we investigated hemorrhagic or parenchymal injuries after intraoperative ventriculostomy using postoperative computed tomographic scan in 26 patients. After standard pterional craniotomy, ventriculostomy catheter was inserted perpendicular to the cortical surface along the bisectional imaginary line from Paine's point.

Results : Hemorrhagic injuries were detected in 12 of 26 patients (46.2%). Mean systolic blood pressure during anesthesia was with in statistically significant parameter related to hemorrhage ($p = 0.006$). On the other hand, parenchymal injuries were detected in 11 of 26 patients (42.3%). Female and the amount of infused mannitol during anesthesia showed statistically significant parameters related to parenchymal injury ($p = 0.005$, 0.04, respectively). However, there were no ventriculostomy-related severe complications.

Conclusion : In our series, hemorrhagic or parenchymal injuries after intraoperative ventriculostomy occurred more commonly than previously reported series in aneurysmal SAH patients. Although the clinical outcomes of complications are generally favorable, neurosurgeon must keep in mind the frequent occurrence of brain injury after intraoperative ventriculostomy in the acute stage of aneurysmal SAH.

KEY WORDS : Brain injury · Subarachnoid hemorrhage · Ventriculostomy.

INTRODUCTION

The placement of a catheter for external ventricular drainage (EVD) of cerebrospinal fluid (CSF) is commonly performed in neurosurgical field. Ventriculostomy is a useful procedure to manage the patients with elevated intracranial pressure (ICP) secondary to acute hydrocephalus caused by intracerebral or subarachnoid hemorrhage (SAH), intraventricular hemorrhage (IVH) and space occupying lesions obstructing the CSF circulation[8,18]. Particularly, in the patient with aneurysmal SAH, brain relaxation is important for safe and rapid operation[5,11,14].

Intraoperative ventriculostomy is considered simple and safe procedure to most neurosurgeons. Although the procedure is widespread and commonly used, it has been associated with various complications (including infection, hemorrhage and parenchymal injury)[6]. Furthermore, the incidence of ventriculostomy-related hemorrhagic or parenchymal injury has been overlooked or underestimated, because postoperative follow up imaging study is not routinely performed, especially in uncomplicated cases, after immediate postoperative stage[17,18].

We present the incidences and characteristics of ventriculostomy-related brain injuries in 26 patients with aneurysmal SAH who received routine follow up by computed tomographic (CT) scans immediately after intraoperative ventriculostomy.

MATERIALS AND METHODS

Study population

From September 2006 to June 2007 at our hospital, a

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total of 43 patients underwent surgical clipping within 48 hours after onset of aneurysmal SAH. Among these patients, 26 patients underwent intraoperative ventriculostomy and CSF drainage to reduce brain swelling due to acute hydrocephalus or thick hemorrhage. SAH was confirmed by CT scans, and location of the aneurysm was determined by 3-dimensional CT angiogram. The brain CT scan was done in every patient immediately after to assess ventriculostomy-related complications. Clinical outcomes after 3 months were evaluated using Glasgow outcome scale (GOS). In patients with GOS scores of 4 to 5, the outcome was classified as favorable; in patients with scores of 1 to 3 were classified as unfavorable. Retrospective reviews of patients' medical records, laboratory data, and radiographic studies were conducted.

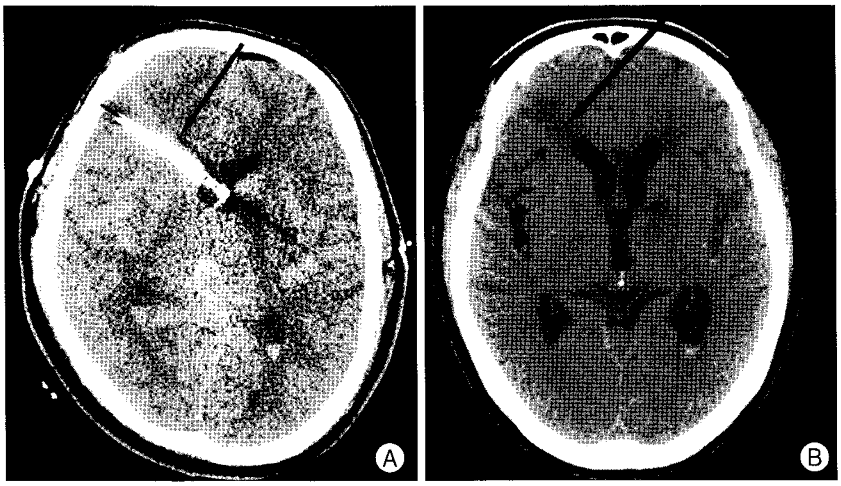

Fig. 1. Brain axial computed tomographic scans showing hyperdense areas (arrow) around the ventriculostomy catheter (A) and hypodense areas (arrow) along the catheter trajectory (B).

Clinical parameters

We investigated clinical parameters including Hunt-Hess grade, Fisher's grade, GOS, location of the aneurysm, and size of the aneurysm. Also, we analyzed laboratory data including initial blood glucose, liver enzymes (Alanine aminotransferase and Aspartate aminotransferase), and common coagulation profiles (activating clotting time, international normalized ratio, prothrombin time, activated partial thromboplastin time, and platelet count) for each patient. In addition, initial systolic and diastolic blood pressures were monitored. During anesthesia, we checked mean systolic and diastolic blood pressure 1 hour before and after ventriculostomy. The amount of drained CSF and infused mannitol during anesthesia, duration of the placement of ventriculostomy catheter, and location of catheter were recorded.

Surgical procedure and management

One neurosurgeon performed ventriculostomy to all patients with brain edema. We inserted a 9.0 Fr. silicone catheter (outer diameter : 3.0 mm, inner diameter : 1.6 mm) perpendicular to the cortical surface along the bisectional imaginary line from Paine's point after pterional craniotomy[11]. The catheter was advanced until CSF was obtained. Maximal insertion depth was 6 cm and no more than three passes were attempted. Ventriculostomy catheter was maintained for 3 to 5 days for ICP monitoring and brain relaxation.

Table 1. Clinical summary of demographic and clinical data in 26 patients studied

Variables	No. of patients
Sex (M/F) (n)	11/15
Age (years, mean ± SD)	55.8 ± 13.2
Hunt-Hess grade	
I	2
II	11
III	5
IV	6
V	2
Fisher grade	
I	0
II	3
III	16
IV	7
Location of aneurysm	
ACA	13
MCA	6
ICA	7
Size of aneurysm	
< 10 mm	23
10-25 mm	3
History of DM	
+/-	0/26
History of HTN	
+/-	12/14

ACA : anterior cerebral artery, DM : diabetes mellitus, HTN : hypertension, ICA : internal cerebral artery, MCA : middle cerebral artery

Imaging studies of ventrculostomy-related brain injuries

Brain CT scan images were obtained in all patients within 2 hours after surgery. After removal of ventriculostomy catheter, additional brain CT scans were obtained in all patients on postoperative 7 days. Two independent neurosurgeons evaluated brain CT scans. Ventriculostomy-related hemorrhage was defined as newly developed hyperdense area adjacent to the catheter or catheter trajectory (Fig. 1A). Also, ventriculostomy-related parehchymal injury was defined as hypodense area adjacent to the catheter or catheter trajectory unrelated to hemorrhagic injury due to catheter insertion (Fig. 1B).

Statistically analysis

We statistically analyzed the association of clinical parameters between complicated patients and non-complicated patients after ventriculostomy. Comparisons between two groups were analyzed using the independent Student's t-test and chi-square test. All data was presented in mean ± standard deviation. The result less than $p < 0.05$ was considered statistically significant.

RESULTS

Demographic characteristics

There was a slight female preponderance in this study group (female to male ratio 1.36 : 1; 57.7% female) and the mean age was 55.8 ± 13.2 years, ranging from 32 to 78 years. The summary of demographic parameters is showed in Table 1.

Parameters related to hemorrhagic or parenchymal injury

Among 26 patients with SAH who underwent venticulostomy during early aneurysm surgery, 12 patients (46.2%) had hemorrhagic complications. There were no significant statistical differences of clinical parameters between hemorrhagic group and non-hemorrhagic group except the mean systolic blood pressure during anesthesia (115 ± 9.84 vs. 104. 58 ± 8.91, $p = 0.006$) (Table 2). In addition, 11 patients (42.3%) had parenchymal injury after ventriculostomy. Female and the amount of infused mannitol during anesthesia were statistically significant parameters that was related to parenchymal injury ($p = 0.005$, 0.04, respectively) (Table 3).

Location of catheter tip

We examined the location of catheter tip on follow up CT scans. Catheter tips were located in the ipsilateral frontal horn of lateral ventricle (10 patients, 38.5%), contralateral frontal horn of lateral ventricle (8 patients, 30.8%), third ventricle (4 patients, 15.4%), and brain parenchyma (4 patients, 15.4%). There was no significant statistical correlation between the location of catheter tips and types of

Table 2. Univariate analysis of clinical and laboratory data in 12 hemorrhagic injured patients after intraoperative ventriculostomy

Variables	Hemorrhagic injury (+)	Hemorrhagic injury (-)	*p* value
Hunt-Hess grade			0.533
I	1	1	
II	7	4	
III	1	4	
IV	2	4	
V	1	1	
Fisher grade			0.524
I	0	0	
II	2	1	
III	8	8	
IV	2	5	
Location of aneurysm			0.660
ACA	7	6	
MCA	3	3	
ICA	2	5	
Size of aneurysm			0.225
< 10 mm	12	11	
10-25 mm	0	3	
Parenchymal injury			0.453
+	4	7	
-	8	7	
ALT (IU/liter)	19.33 ± 9.47	29.35 ± 28.00	0.249
AST (IU/liter)	26.66 ± 11.81	37.35 ± 21.76	0.142
INR	0.97 ± 0.94	0.96 ± 0.64	0.654
ACT (secs)	108.38 ± 14.10	108.46 ± 11.13	0.988
PT (secs)	11.95 ± 0.82	11.84 ± 0.58	0.681
aPTT (secs)	27.75 ± 2.19	27.43 ± 2.15	0.709
PLT ($\times 10^3/\mu L$)	304.83 ± 69.27	252.85 ± 109.47	0.169
Blood glucose (mg/dL)	136.00 ± 27.40	154.64 ± 38.09	0.171
Initial systolic BP (mmHg)	155.83 ± 26.09	154.28 ± 28.74	0.887
Initial diastolic BP (mmHg)	89.16 ± 13.78	87.85 ± 13.68	0.811
MSBP during ANES (mmHg)	115.57 ± 9.84	104.58 ± 8.91	0.006
MDBP during ANES (mmHg)	61.91 ± 9.10	56.91 ± 7.97	0.148
Drained CSF (mL)	41.25 ± 7.42	45.00 ± 8.54	0.243
Amount of mannitol (mL)	133.50 ± 98.22	71.57 ± 91.26	0.112
Duration of EVD (hours)	99.25 ± 36.19	99.28 ± 40.50	0.998

ACA : anterior cerebral artery, ACT : activated clotting time, ALT : alanine aminotransferase, ANES : anesthesia, aPTT : activated partial thromboplastin time, AST : aspartate aminotransferase, BP : blood pressure, CSF : cerebrospinal fluid, EVD : external ventricular drainage, ICA : internal cerebral artery, INR : international normalized ratio, MCA : middle cerebral artery, MDBP : mean diastolic blood pressure, MSBP : mean systolic blood pressure, PLT : platelet, PT : prothrombin time

Table 3. Univariate analysis of clinical and laboratory data in 11 parenchymal injured patients after intraoperative ventriculostomy

Variables	Parenchymal injury (+)	Parenchymal injury (-)	*p* value
Hunt-Hess grade			0.327
I	1	1	
II	3	8	
III	3	2	
IV	4	2	
V	0	2	
Fisher grade			0.368
I	0	0	
II	0	3	
III	8	8	
IV	3	4	
Location of aneurysm			0.063
ACA	7	6	
MCA	4	2	
ICA	0	7	
Size of aneurysm			0.556
< 10 mm	9	14	
10-25 mm	2	1	
Hemorrhagic injury			0.453
+	4	8	
-	7	7	
ALT (IU/liter)	17.90 ± 10.17	29.73 ± 26.60	0.176
AST (IU/liter)	28.27 ± 10.25	35.46 ± 22.44	0.334
INR	0.99 ± 0.09	0.94 ± 0.60	0.134
ACT (secs)	103.78 ± 14.10	111.83 ± 12.26	0.134
PT (secs)	12.12 ± 0.82	11.72 ± 0.54	0.149
aPTT (secs)	26.70 ± 2.07	28.23 ± 2.00	0.070
PLT ($\times 10^3$/μL)	291.72 ± 49.57	265.93 ± 118.70	0.506
Blood glucose (mg/dL)	159.09 ± 39.22	136.46 ± 27.69	0.097
Initial systolic BP (mmHg)	154.54 ± 29.44	155.33 ± 26.14	0.943
Initial diastolic BP (mmHg)	89.09 ± 14.45	88.00 ± 13.20	0.843
MSBP during ANES (mmHg)	111.11 ± 11.87	108.58 ± 10.10	0.575
MDBP during ANES (mmHg)	63.03 ± 8.47	56.43 ± 8.03	0.058
Drained CSF (mL)	42.27 ± 9.04	44.00 ± 7.60	0.602
Amount of mannitol (mL)	54.72 ± 81.88	133.46 ± 97.39	0.040
Duration of EVD (hours)	100.00 ± 36.87	98.73 ± 39.76	0.935

ACA : anterior cerebral artery, ACT : activated clotting time, ALT : alanine aminotransferase, ANES : anesthesia, aPTT : activated partial thromboplastin time, AST : aspartate aminotransferase, BP : blood pressure, CSF : cerebrospinal fluid, EVD : external ventricular drainage, ICA : internal cerebral artery, INR : international normalized ratio, MCA : middle cerebral artery, MDBP : mean diastolic blood pressure, MSBP : mean systolic blood pressure, PLT : platelet, PT : prothrombin time

Table 4. Univariate analysis of location of catheter tip and complicated patients after intraoperative ventriculostomy

Location of catheter tip	Hemorrhagic injury (+/-)	Parenchymal injury (+/-)
Ipsilateral LV frontal horn	5/5	1/9
Contralateral LV frontal horn	4/4	5/3
Third ventricle	1/1	2/0
cistern	1/1	1/1
parenchyma	1/3	2/2
p value	0.931	0.075

LV : lateral ventricle

injury ($p > 0.05$) (Table 4).

Postoperative course after ventriculostomy

In overall, 18 patients (69.2%) had favorable outcome (good recovery in 17 and moderate disability in 1). One patient (3.8%) had severe disability, 4 patients (15.4%) remained in a vegetative state, and 3 patients (11.5%) expired. Outcome was not significantly correlated with types of injury ($p > 0.05$) (Table 5).

DISCUSSION

In aneurysmal SAH, intraoperative ventriculostomy is useful technique to drain the CSF with brain edema. Since Paine et al.[11] suggested intraoperative access to the lateral ventricle in 1988, some investigators have announced several intraoperative entry points to the lateral ventricle[5,10,13]. During supraorbital craniotomy via eyebrow incision, the key hole just behind the zygomatic process of the frontal bone is a useful landmark for ventricular puncture of the lateral ventricle[10]. Also, intraoperative ventricular puncture can be performed by using the landmark described by Paine which is 2 cm beyond the line extending from the anterior limb of the triangle or 2.5 cm superior to the lateral orbital roof and 4.5 cm anterior to the sylvian fissure[5,13]. However, under angered and edematous brain, intraoperative ventricular puncture is not always accessible. It may need several attempts for ventricular puncture.

The most common complication of ventriculostomy is infection. Ventriculostomy-related infections have been widely investigated and reported with rates of 0 to 22%[8]. However, other complications such as hemorrhagic and parenchymal injury have been infrequently reported. Although

Table 5. Univariate analysis of Glasgow outcome scale and complicated patients after intraoperative ventriculostomy

Glasgow outcome scale	Hemorrhagic injury (+/-)	Parenchymal injury (+/-)
Good recovery	9/8	8/9
Moderate disability	0/1	1/0
Severe disability	1/0	0/1
Persistent vegetative state	0/4	2/2
Death	2/1	0/3
p value	0.125	0.372

clinically trivial intracerebral hemorrhage is occasionally observed after ventriculostomy, some investigators have reported true incidence of ventriculostomy-related hemorrhage through routine CT scan immediately after ventriculostomy[3,9,18]. On the literatures, the overall incidence of ventriculostomy-related brain injuries have been reported variably from 0.3 to 81%[2,9,12,16-18].

In 2001, Tominaga et al.[17] reported magnetic resonance (MR) imaging findings after ventriculostomy and concluded that occurrence of brain injuries was extremely frequent on the MR images (81%). Also, 33% overall rate of ventriculostomy related hemorrhage was reported by Maniker et al.[9]. These incidences are much higher than previously reported cases. These discrepancies of incidence may ascribe to several factors. First, follow up imaging study were not performed routinely in uncomplicated cases during immediate postoperative stage at every hospital[17,18]. Second, true incidence might be masked or underestimated because ventriculostomy-related brain injuries enough to manifest relatively low significant change in the neurological status of patients. Also, preexisting neurological deficits may hinder the detection of ventriculostomy-related brain injuries[1,2,9,17,18]. Third, there were differences on study designs and surgical procedures in every reported cases. Consistent with recent reports[9,17], we found high overall incidence of brain injuries after intraoperative ventriculostomy.

In our study, hemorrhagic injury was correlated with mean systolic blood pressure during anesthesia. Therefore, tight blood pressure control at the time of ventriculostomy might be important. On the other hand, female and the amount of infused mannitol during anesthesia were statistically significant parameters related to parenchymal injury. However, the exact reasons for this correlation are unclear. Further studies should investigate the relationship of these factors to the incidence of parenchymal injury related ventriculostomy. As aforementioned, brain injuries associated with ventriculostomy have been rarely reported and the mechanism of brain injuries are uncertain. On the literatures, some case reports presented the possible mechanism of brain injuries, however, there was no analysis about brain injuries after intraoperative ventriculostomy using Paine's point. Some possible explanations for hemorrhagic injury included cerebrovascular disease, puncture adjacent to infarction area, coagulopathy and direct vascular trauma by the catheter[9,15]. As for parenchymal injury, Tominaga et al.[17] suggested that widening and gliosis of puncture tract were accounted for low density lesions on the CT scans. From our series, as it was difficult to find exact cortical entry in brain edema, dysautoregulated microvessel and parenchyma were more susceptible to pass a catheter, therefore, brain injury might have been occurred more frequently than previous reports using Kocher's point.

The shortcoming of intraoperative ventriculostomy in the patients with aneurysmal SAH is rough and blind insertion of a catheter in brain edema and displaced ventricle. Some investigated the efficacy of lumbar drain (LD) in the setting of aneurysmal SAH[4,7]. Although they reported that lumbar CSF drainage is safe and effective method to decrease the incidence of vasospasm, LD has some limitations. First, the diameter of lumbar drainage catheter is usually smaller than that of ordinary EVD catheter. Therefore, thick blood clot in subarachnoid space may obstruct the LD catheter. Second, in the incidence of high ICP, LD may cause downward brain herniation. Third, spinal epidural hematoma, infection and meningitis may occur after LD. Regarding these differences further study will be needed to compare the safety between EVD and LD.

There are some limitations to this study that need to be addressed. First, the total number of study group is relatively small and the conclusion drawn from the current data set may not be universally applicable. Second, we could not perform MR imaging in every cases although It is essential tool for accurate assessment of brain injury. Finally, we could not perform a reliable cognitive comparison using psychometric tests in this study population. Psychometric tests may reveal other complications including high cortical function disorders.

CONCLUSION

In this study, overall outcome was not significantly correlated with brain injuries related to intraoperative ventriculostomy in SAH patients. However, neurosurgeon must keep in mind the frequency of brain injury after intraoperative ventriculostomy in the acute stage of aneurysmal SAH.

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